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PROGRESS REPORT

LONG TERM RELIABILITY INVESTIGATIONS

OF THE

MSC-1330 MICROWAVE POWER TRANSISTOR

AND THE

AMPAC 1214-30 INTERNALLY MATCHED DEVICE

Report No. 3 March 10, 1975

Contract No. N00014-74-C-0362

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for

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QUARTERLY REPORT NO. 3  
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Long Term Reliability Investigations of the MSC-1330 Microwave Power Transistor and the AMPAC Internally Matched Device.

I. Purpose

The objective of this program is to establish the median-time-to-failure (MTF) of the MSC-1330 transistor series using long term accelerated RF life tests of the order of 10,000 hours duration.

II. Progress

- The following matrix summarizes the long term test program plan and the test status to date:

LIFE TEST MATRIX

TEST	OBJECTIVE	DEVICE	METAL	T <sub>j</sub> (°C)	STATUS (3/10/75)	NO.OF /SAMPLE FAILURES /SIZE	MTF (est. hrs.)
T <sub>10</sub>	Extend previous 340°C, 280°C, and 250°C data	1330/B	Aluminum	190	On Test* 2860 hrs. No failures	0/8	11,000
T <sub>11A</sub>	Comparison: Refractory Metal vs. aluminum(T <sub>2</sub> ) high temp/same device	1330/A	Refractory Metal	280	On Test* 3620 hrs. 1 failure at 2500 hrs.	1/10	5,600
T <sub>11B</sub>	Comparison: 82010 vs. 1330/A (T <sub>11A</sub> )-same metal	82010	Refractory Metal	280	On Test* 3420 hrs. No failures	0/10	7,700
T <sub>12</sub>	Comparison: Refractory Metal vs. aluminum(T <sub>10</sub> ) low temp/same device	1330/A	Refractory Metal	230	On Test* 3090 hrs. No failures	0/8	> 7,800
T <sub>13</sub>	Comparison: AMPAC vs. discrete device(T <sub>10</sub> )	AMPAC 1214-30	Aluminum	190	IR Scan	-/5	----
T <sub>14</sub>	Comparison: T <sub>j</sub> uncontrolled/no tuning vs. T <sub>j</sub> constant(T <sub>13</sub> )(T <sub>14</sub> simulates actual RF AMPAC operation)	AMPAC 1214-30	Aluminum	190	IR Scan	-/5	----

TOTAL

SAMPLE = 46  
SIZE

NOTE:

Pulse Width = 120 usec, duty factor = 30% for all tests.  
\* New status since last report.

2. The long-term test of the aluminum metallized 1330/B at 190°C (T10) has run for 2860 hours with no failures. Power output for the 8 devices was down an average of 0.9dB with one device down a maximum of 1.7dB. This device will probably "fail" at roughly 3100 hours, based on extrapolation of its power output vs. time. Thus, using the same failure distribution slope as that of the next closest test, T9 (the same device but at 2500°C), then the projected MTF of T10 is roughly 10,000-11,000 hours as shown in Figure 1. If confirmed, this MTF will fall on the straight-line extrapolation of the previous MTF vs. Tj data generated at 340°C, 280°C, and 250°C as shown in Figure 2. Thus, MTF projections down from 190°C to "normal" Tj values (100-140°C) would have greater confidence than those made previously by assuming a constant slope below 250°C.
3. Test T11A of the refractory metallized 1330/A at 280°C has run 3620 hours with only one failure at 2500 hours. Using the same general procedure outlined for T10 above and assuming the same failure distribution slope as T2 (Aluminum metallized 1330/A at 280°C), an MTF of 5600 hours is projected for T11A. The same device at the same Tj with aluminum metallization had a MTF of 480 hours (T2) - with the 8th and final device failing at 1100 hours. Thus, the MTF of the refractory metallized 1330/A at 280°C is projected to, at least, 2 times higher than the same device at the same temperature with aluminum metallization.
4. An equipment failure occurred on Test T11A which could have shortened the life of some or all of the devices. On February 13, 1975, at approximately 3430 hours into the test, it was discovered that the temperature controller had failed causing the hot plate temperature to rise 100°C from the intended 170°C to 270°C. After noting that all devices were still functioning even at this elevated temperature, the test rack was shut down. The device junction temperatures had last been IR scanned and found to be normal 17 hours earlier. The controller failure was traced to pitted contacts on the heater control relay which had fused closed, allowing the heater elements to run continuously. The three other tests were, therefore, interrupted and the heater relay contacts in all temperature controllers were replaced. As a long range solution, thermostatic cutout switches were ordered which will open the heater circuit if the hotplate temperature rises above a predetermined safe value for any reason. This should prevent similar mishaps in the future.
5. The majority of the devices on T11A showed no significant degradation in power output after the temperature controller failure (6 out of 9 test devices had <0.1dB change in P<sub>o</sub>). One device, however, showed a significant degradation of 1.1dB after the failure, while 2 devices showed increases in power output of 0.3dB and 0.8dB. Some degradation in power output may be expected, since bench tests of 3 sample devices under the approximate conditions of the controller failure indicated maximum junction temperatures of 420-470°C, at which the devices failed. The apparent increase in power output for 2

5. devices could have been due to the fact that all device leads had to be resoldered to the circuit lines after the controller failure, making necessary some minor retuning of some circuits to maintain the desired peak junction temperature. It should be noted, however, that no significant change in junction thermal profile was observed for any of the test devices as a result of the controller failure.
6. The first refractory metallized 1330/A to fail on T11A was analyzed using the Scanning Electron Microscope (SEM). This device had degraded to -5.4dB Po at 2520 hours and was found to have failed totally (burned out) at 2688 hours. Examination revealed that 5 of the 12 connected cells located around the center of the pellet were severely damaged and melted. DC static tests indicated an emitter-base short circuit, the predominant failure symptom noted in the previous test series for aluminum metallized devices.

Fortunately, the cell which had been the hottest was not one of those severely damaged in the burnout. SEM examination of this cell shows clearly a growth or extrusion of amorphous material laterally from the emitter fingers shorting to the base fingers at the approximate location of the original hot spot. Photographs taken prior to glass removal also show what appear to be cracks in the glass over the extruded material. In addition, there appears to have been a movement of metal on the emitter fingers away from the ballast resistors towards the center of the cell (in the direction of electron flow). The failure mechanism, thus, seems clearly to be electromigration in the emitter fingers, with the resulting buildup of metal causing short circuits to the base fingers.

7. Test T11B of the refractory metallized 82010 at 280°C has run over 3420 hours with no failures. At 3420 hours, the average power output for the 10 devices was down by only 0.05dB, with one unit down a maximum of only 0.2dB. Making a worst case MTF calculation, it is assumed that the first unit fails at this point (3420 hours). Using the same failure distribution slope as T2 (Aluminum 1330/A also at 280°C), the MTF is projected to be at least 7700 hours. This is at least 16 times greater than for the aluminum 1330/B device at the same temperature (T2).
8. The long-term test of the refractory metallized 1330/A at 230°C (T12) has run over 3090 hours with no failures. At 3090 hours, the average power output was down by only 0.06dB, with one unit down a maximum of 0.2dB. If the first device had failed at this point, the projected MTF would be at least 7800 hours or more than 3 times greater than the 2300 hour MTF of the aluminum metallized 1330/A at the same Tj (230°C) as given by Figure 2. As in the previous calculations, this assumes the same failure distribution slope for the nearest previous test, T3, (aluminum 1330/A at 250°C).

9. The program schedule is shown in Figure 3. It will be noted that all tasks are proceeding on schedule, but for tests T13-T14 (aluminum metallized 1214-30 AMPAC at 190°C) to start as originally scheduled by June 1, 1985, test T11A will have to be terminated by May 15, 1975. This would correspond to a maximum running time for T11A of 5200 hours, by which time less than half of the original group of test devices will probably have failed. Consequently, final plans for these tests will have to be reviewed and decided upon within the next 2 months.

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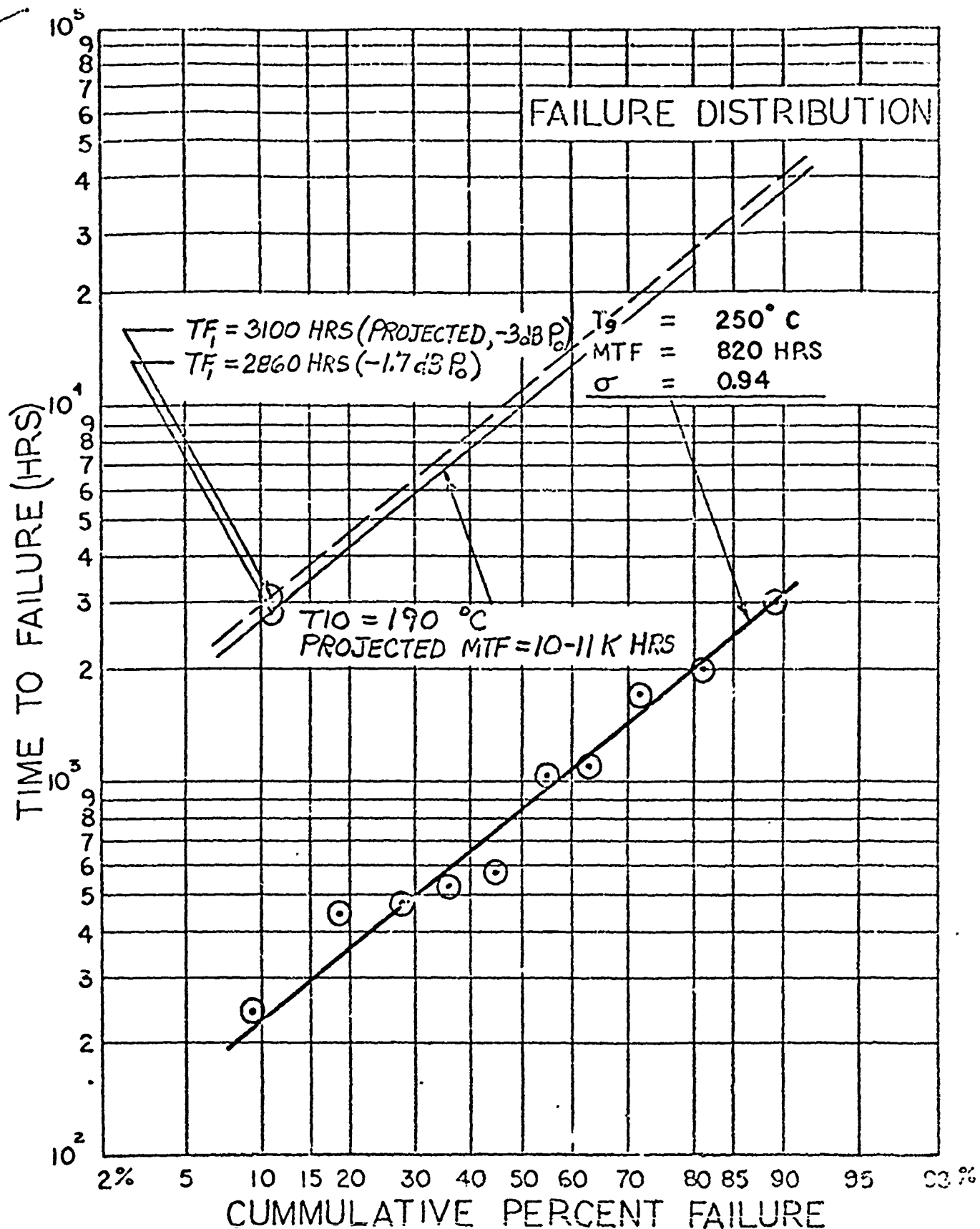


FIGURE 1 - Projected T10 Failure Distribution and Final T9 Failure Distribution

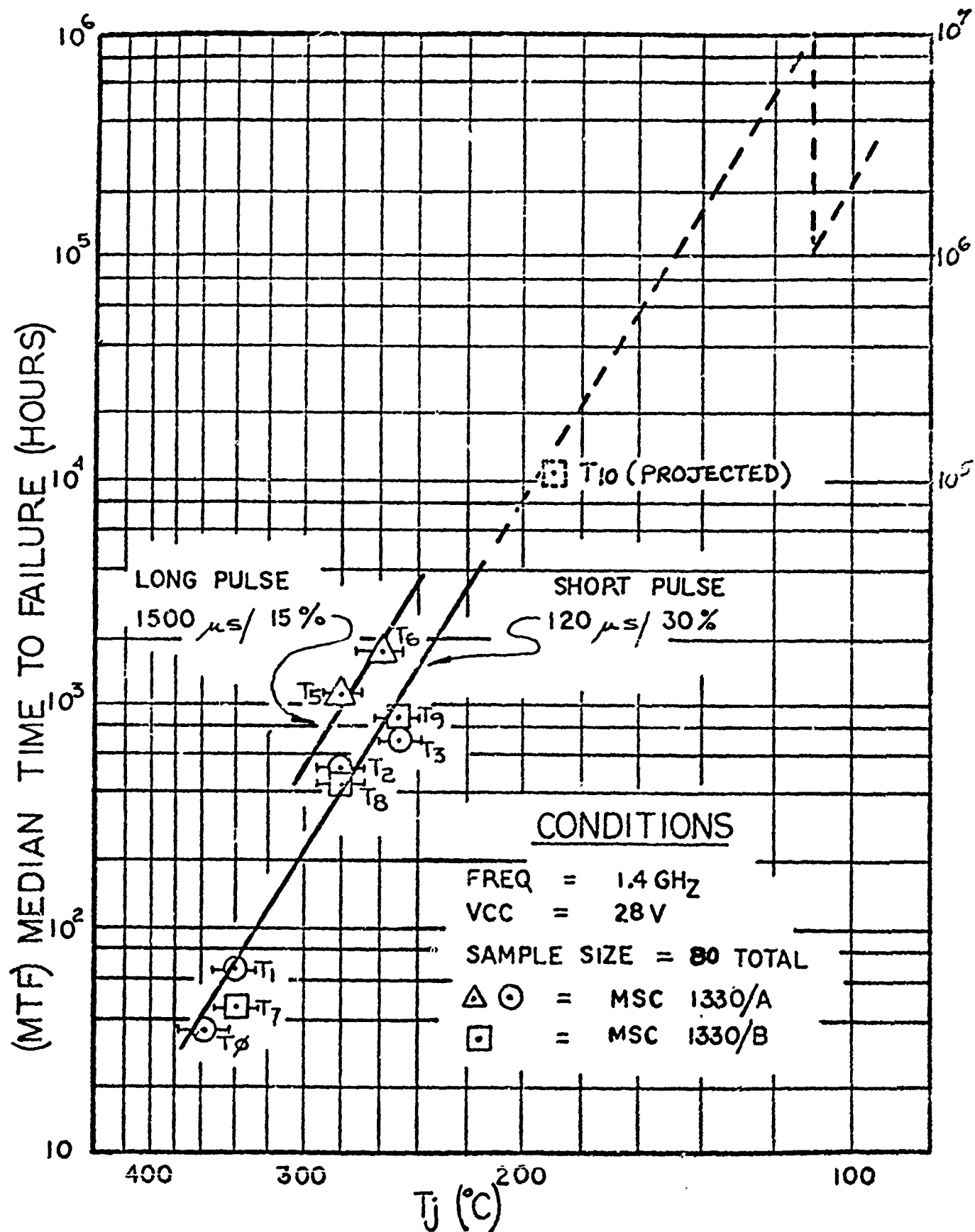


Figure 2 - Median-Time-to-Failure vs. Peak Junction Temperature

1975

Task	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
A. BUILD CIRCUITS												
1. 50 POWER TRANSISTORS												
2. 20 POWER MOSFETS												
B. MODIFY RACKS												
1. CONVERT TO 100% (2)												
2. DESIGN & BUILD IN MOUNT												
3. INSTALL IN MOUNT												
C. PREPARE DEVICES												
1. ASSEMBLE DEVICES												
2. BURN IN DEVICES												
D. RUN LIFE TESTS												
1. T10 - (12) 1250A												
2. T11 - (*) 1250A												
3. T12 - (*) 22010												
4. T13 - (*) 1250A												
5. T14 - (12) 1250A												
(1250A AMEND)												
* REFRACTORY METAL												

DATE: 3/10/75

BY: LGW